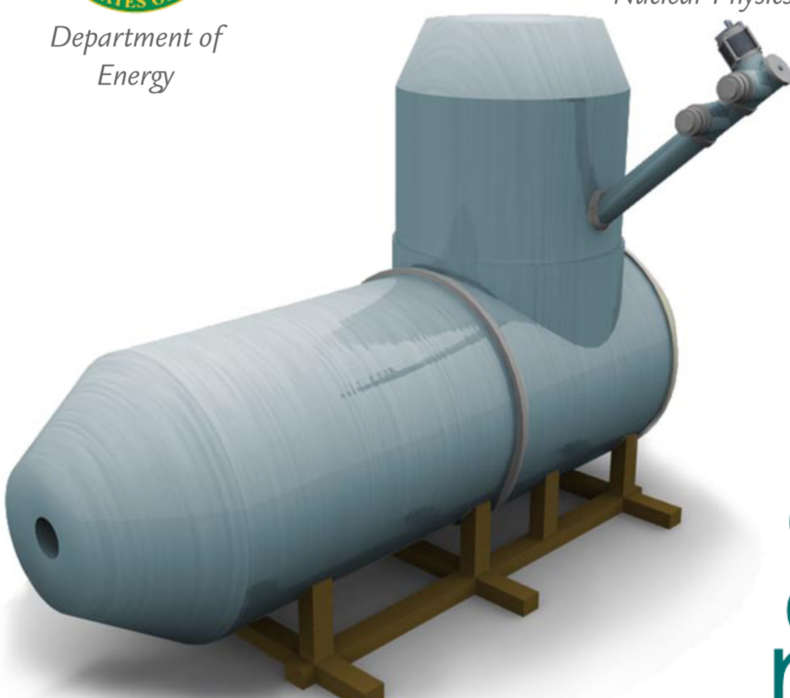
Neutron Electric Dipole Moment Project

Office of Science

Office of Nuclear Physics

Department of Energy



Preliminary Hazard Identification & Analysis Plan

Signature Approvals

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Table of Contents

List of Acronyms and Abbreviations

ACGIH	American Conference of Governmental Industrial Hygienists
ASME	American Society of Mechanical Engineers
CW	continuous wave
DOE	Department of Energy
dTPB	deuterated tetraphenyl butadiene
EIS	environmental impact statement
EDM	electric dipole moment
FM	factory mutual
FNPB	Fundamental Neutron Physics Beamline
FSAD	Final Safety Assessment Document (SNS Document 102030102-ES0016)
IPPS	instrument personnel protection system
ISMS	integrated safety management system
LANL	Los Alamos National Laboratory
LO/TO	lockout/tagout
MSDS	material safety data sheet
NCSU	North Carolina State University
NEC	National Electric Code
nEDM	electric dipole moment of the neutron
NEPA	National Environmental Policy Act
NFPA	National Fire Protection Association
ODH	oxygen deficiency hazard
OPM	operations procedures manual
ORNL	Oak Ridge National Laboratory
OSHA	Occupational Safety and Health Administration
PPE	personnel protective equipment
RF	radio frequency
RSS	research safety summary
SBMS	standards-based management system
SNM	special nuclear material
SNS	Spallation Neutron Source (ORNL)
TLV	threshold limit value
TUNL	Triangle Universities Nuclear Laboratory
UCN	ultracold neutrons
UL	Underwriters Laboratories
XFD	Experimental Facilities Division of the SNS

1.0 Introduction

This document describes the preliminary hazard identification and analysis performed for the neutron Electric Dipole Moment (nEDM) experiment. nEDM will be constructed by the collaborating institutions and executed at the Fundamental Neutron Physics Beamline (FNPB) at the Spallation Neutron Source (SNS), located at Oak Ridge National Laboratory (ORNL). The project office for the nEDM experiment is located at Los Alamos National Laboratory (LANL).

The SNS is an accelerator-based neutron source in Oak Ridge, Tennessee, built by the U.S. Department of Energy (DOE). The SNS will provide the most intense pulsed neutron beams in the world for scientific research and industrial development. At a total cost of $1.4 billion, SNS construction was recently (2006) completed. The SNS is a national user facility, open to scientists from universities, industries, and federal laboratories. It is anticipated that the facility, when fully operational, will be used by 1,000–2,000 scientists each year. The SNS target station has the capacity to host 24 beamlines (instruments).

The FNPB is located on SNS beamline #13, which views one of the cold, coupled, unpoisoned moderators (the moderator type with the highest fluence). The FNPB has two separate experimental areas. One experimental area, inside the main SNS target building is suitable for experiments (such as precision measurements of neutron β-decay correlations and parity-violation) that can make use of the full neutron energy spectrum. A second experimental area will be located in a building outside the main target building (where it can be isolated from vibrations and radioactive backgrounds) and is suitable for experiments that study ultracold neutrons (UCNs) generated by stopping neutrons of a particular energy (or wavelength, λ ~0.89 nm) inside liquid helium-4. The nEDM experiment will be assembled and operated inside this external building. Figure 1 shows a schematic drawing of the nEDM apparatus.

The nEDM apparatus consists of a number of separate subsystems (the cryogenic vessel, the magnetic coils and shielding, the central detector system, the helium-3 system, and neutronics [neutron guide and shielding]). These subsystems will be developed and tested at collaborating institutions. The magnetic coils, central detector system, and the helium-3 system will be assembled into the cryogenic vessel at the SNS FNPB, integrated with the neutronics and the magnetic shielding, commissioned, and operated.

In this document, we define the hazards that will be encountered at the SNS during assembly, commissioning, and operation. We also discuss the corresponding SNS policies and procedures and list some possible mitigation techniques. Hazards that may be encountered at other collaborating institutions (during development and testing of various subsystems before the final assembly) are subsets of the hazards listed here. The general policy of the nEDM collaboration is that all work will be performed safely under the policies of the institution where the work is being done. Hazard Analysis results, mitigation techniques, and associated procedures will be communicated to cognizant authorities at all institutions where related work will be carried out. The LANL project office will examine operations at the institutions to verify that they are consistent with LANL safety principles, as documented in Integrated Work Management, IMP-300. It should be noted that the other institutions where work will be performed are universities governed by OSHA regulations and other national labs. Web links to some of the Environmental, Safety, and Health homepages are listed here:

University of Illinois, Urbana-Champaign	http://phantom.ehs.uiuc.edu/
University of California, Berkeley	http://ehs.berkeley.edu
North Carolina State University	http://www.ncsu.edu/ehs/healthsafety_man.htm
Arizona State University	http://www.asu.edu/uagc/EHS/
California Institute of Technology	http://www.safety.caltech.edu/home.htm
Massachusetts Institute of Technology	http://informit.mit.edu/ehs-ms/
Duke University	http://www.safety.duke.edu/

All work in the SNS FNPB will be performed within SNS and ORNL Integrated Safety Management System (ISMS) and Standards Based Management System (SBMS) requirements and safe work practices. By following applicable ORNL, SNS, and ORNL Physics Division procedures, as well as applicable codes and standards, hazards will be eliminated or controlled to ensure a safe work environment.

SNS Document 102030102-ES0016, *Spallation Neutron Source Final Safety Assessment Document for Neutron Facilities* (FSAD), is the safety document for beamlines at the SNS. A number of nEDM components, including reflective neutron guides, beam benders, secondary shutters, beam monitors, neutron beamline vacuum systems, magnets, neutron beamline utilities, and neutron beamline shielding are similar in form and function to other beamlines at the SNS. These items are described in Section 3.3.13 of the FSAD. The potential hazards posed by elements common to all or some of the beamlines are addressed in Section 7 of the FSAD. The FSAD also addresses many standard industrial hazards, such as flammable materials and chemical storage, crane and forklift usage, etc.

Because the experiment will ultimately be a resident within the SNS facility, it will be subject to all applicable SNS quality-assurance and safety requirements for component design and certification and hazard-mitigation techniques. To ensure compliance with SNS requirements, we will conduct comprehensive design reviews, at appropriate stages of the design, with participation by representatives of the SNS Experimental Facilities Division (XFD). Safety officers from collaborating institutions will be included in the design reviews, as necessary, to ensure that component design and certification and hazard-mitigation techniques satisfy requirements at all institutions where the corresponding work will be performed.

As with all experiments at the SNS, nEDM will be subject to a comprehensive Safety Readiness Review before instrument commissioning as described in Section 3.4.6 of the FSAD.

Environmental consequences of SNS instruments were addressed in the SNS Environmental Impact Statement (DOE/EIS-0247). No additional National Environmental Policy Act (NEPA) documentation is required. As a result, the hazard analysis contained in this document does not address these issues.

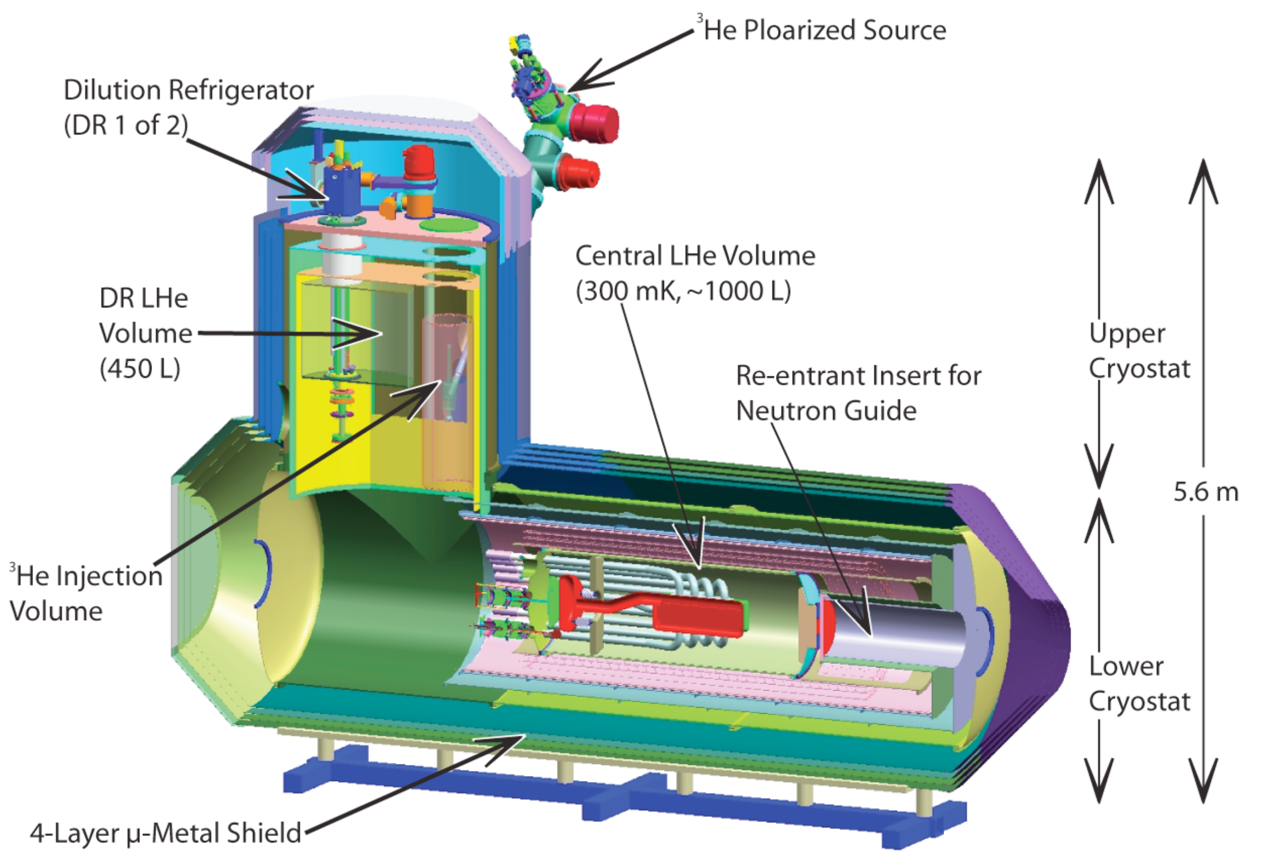

Figure 1. Schematic diagram of nEDM apparatus.

2.0 Hazard Identification and Analysis

To initiate the hazard screening process for nEDM, we used the screening tables (Tables A-1–A-5) shown in Appendix A. Many of the identified hazards are addressed within the existing SNS FSAD. However, a number of identified hazards require some more discussion and analysis. These include radiation (ionizing and nonionizing), laser, fire, magnetic field, oxygen deficiency, vacuum and pressure, cryogenic, elevated work, chemical, hoisting and rigging, confined space, and electrical hazards.

2.1 Accelerator Hazards

While the SNS is an accelerator facility, nEDM operation does not involve direct interaction with the accelerator except through the Instrument Personnel Protection System (IPPS). The IPPS can initiate a sequence of events that halts accelerator operation.

2.2 Radiation and Radioactive Materials Hazards

Tests of the nEDM experiment with radioactive sources (α and β) are anticipated.

Accessing the experimental apparatus with the primary and secondary shutters open is a potential hazard. Exposure to the neutron beam may activate components of the experimental apparatus, which could also lead to contamination hazards. Note: The nEDM beamline only transmits a narrow energy slice of neutrons and never sees the moderator or the prompt neutron or γ-flash because the input neutrons pass through a double monochromator. As such, radiation hazards and activation are expected to be minimal.

nEDM radiation hazards are subject to SNS and ORNL policies and procedures. Source usage is subject to ORNL and SNS policies and procedures. Radiation limits for the Target Building and external instrument buildings have been set in accordance with the SNS Shielding Policy, including a requirement of less than 0.25 mrem/hr in unrestricted areas and a goal of less than 2 mrem/hr in areas with restricted access. The SNS Operations Procedures Manual (OPM) includes the administrative procedures that implement these policies.

2.3 Nonionizing Radiation Hazards

The nEDM experiment incorporates two types of radio-frequency (RF) generators:

1. RF spin flippers (one for each of the two measurement cells) will be used to alternate the neutron spin orientation entering the cells. It is anticipated that these will operate at 20–40 kHz, with a maximum total power of a few hundred Watts.
2. “Dressing coils” will be used to equalize the neutron and helium-3 comagnetometer precession frequencies. These are anticipated to operate at 3 kHz with a power of only a few Watts.

Occupational exposures will remain below the Threshold Limit Values (TLV) in the latest ACGIH (American Conference of Governmental Industrial Hygienists) TLV booklet, as per ORNL SBMS policy. Detailed analysis will be required to determine required warning postings and whether access will be restricted during operation.

2.4 Magnetic Field Hazards

Both static and time-varying magnetic fields will be used. Static fields to guide the neutron spin will be in the 5–10 Gauss range along the neutron beamline. Static guide fields inside the measurement cell will be smaller (1 Gauss) and extremely well-shielded. Time-varying fields inside the apparatus, from the RF Spin Flippers and “Dressing coils” described in Section 2.3, are much smaller.

The SNS policy on magnetic fields, described in Section 7.5 of the FSAD, states that regions with fields greater than or equal to 5 Gauss must be plainly marked and posted with signs stating “No Pacemakers or Other Medical Electronic Devices.” Furthermore, personnel involved in operating, maintaining, and testing magnets will be trained in the associated hazards.

2.5 Laser Hazards

The nEDM will incorporate a laser to allow measurement of the voltage applied to the measurement cell through the Kerr effect (rotation of laser polarization is dependent on the material and the field). The laser is likely to be a CW (continuous-wave) frequency-doubled Nd:YAG laser, 532 nm, 10 mW. This laser is classified as Class 3B by ORNL SBMS.

ORNL SBMS specifies requirements for working with lasers, which includes but is not limited to, training, administrative and engineering controls, a standard operating procedure, and medical surveillance (eye exam).

2.6 Fire Hazards

The only flammable materials in the nEDM experiment are cables (which will be subject to SNS flammability regulations), the small amount of polystyrene in the measurement cell (which will be encased in the metallic cryostat vessel, and which will be in a pool of liquid helium during operation), and (possibly) hydrocarbon-based shielding components.

SNS is following National Fire Protection Association (NFPA) 101 “The Life Safety Code” for matters relating to personnel fire protection. SNS OPM Section 2.J-2 and the FSAD Sections 3.3.10.3 and 7.4 deal with fire-protection systems. In addition, SNS OPM 7.T-200.5, “Target Building Combustible Controls” contains requirements that must be met (e.g., 100 lbs of hydrocarbon shielding requires additional review).

2.7 Oxygen Deficiency Hazards

The nEDM experiment contains roughly 1500 L of liquid helium. If this became gas in the nEDM building, it would displace sufficient amounts of air to become an asphyxiation hazard. A cryostat blow-off would be readily detectable by someone in the room. These personnel will be trained to leave the room immediately under such circumstances. Of primary concern would be entry into the building after such an event has occurred and for which the warning signs (vapor cloud, venting sounds) are no longer present.

SBMS policies and procedures, supplemented by SNS policies ensure that any needed mitigation features (e.g., safety interlocks or alarms) are employed. Appropriate protection, training, and procedures are required to ensure that the hazard is appropriately mitigated in all phases of design and operation. Cryogenic-system design and operations will be subject to review by the SNS Cryogenic Safety Review Committee.

2.8 Vacuum and Pressure Hazards

The neutron guide (like many in the SNS) and the experimental apparatus will be operated under vacuum. Vacuum systems at the SNS must be designed to meet, withstand, or eliminate the full range of stresses encountered in vacuum service and are subject to the general instrument safety-review process.

When the experimental apparatus is not in operation the liquid helium will be in a storage tank situated outside the nEDM building. This pressure vessel will be subject to ORNL SBMS policies and procedures which require ASME certification and stamp or vendor certification of maximum allowable working pressure.

Loss of insulating vacuum in the experimental apparatus would heat the liquid helium rapidly, possibly resulting in a sudden release of high-pressure gasses. The apparatus will be engineered with redundant and tested pressure-release valves. A testing program in accordance with SNS-QA-P081 will be developed to periodically evaluate the performance of the valves. The principal release path will be to the storage tank mentioned above. In the advent of blockage of this path, there will be a higher-pressure release path into atmosphere. In the case of a sudden release that exceeds the flow capacity of the standard lines, a large emergency-vent valve and line will be installed to exhaust the helium outside the building.

During the transfer of cryogens, the possibility of trapping water or air in lines can lead to blocked passages and isolated volumes. These volumes can become overpressured. The transfer of cryogens can be accomplished without trapping water or air by the use of proper techniques. All workers who transfer cryogens will be required to have job-specific training to ensure they understand the hazards of frozen gases and how to prevent such occurrences. In addition, an analysis will be done to identify all spaces in the system that can become isolated, and pressure-relief valves will be installed for these volumes.

2.9 Cryogenic Hazards

Transfer of liquid nitrogen and helium are considered to be standard industrial practice. Personnel involved in such operations are required to receive adequate cryogenic-safety training and to follow "Safety for Cryogenic Operations at the SNS." Appropriate safety equipment will be required when handling cryogenic fluids. Instrument components designed for cryogenic use are reviewed by the SNS Cryogenic Safety Review Committee.

2.10 Elevated Work Hazards

The nEDM apparatus rises 6 m above the floor of the nEDM building. OSHA-compliant ladders and platforms will be part of the project. Under unusual circumstances, it might be necessary to work outside the platform structure. In these cases an SBMS or OSHA-compliant fall-protection plan will be utilized. In all cases, appropriate training will be required.

2.11 Chemical Hazards

Most chemical hazards associated with the nEDM experiment will be common to many experiments at the SNS (small quantities of acetone and/or alcohol for cleaning surfaces, lead shielding, solder, pump-oil waste, etc.).

In addition to these standard chemicals, nEDM will likely use thin beryllium foils in the neutron entrance window. Any work with beryllium will be independently reviewed. Beryllium activities will be conducted under ORNL Physics Division (or a project-specific) beryllium protection plan and may require a job-specific beryllium work plan.

Lithium-6 may be incorporated into shielding element. Although not hazardous, lithium-6 is Special Nuclear Material (SNM) and any use of SNM will be in accordance with the Security Plan for the SNS Material Balance Area.

Also, during construction of the measurement cells a deuterated wavelength shifter, tetraphenyl butadiene (dTPB) will be applied to the surface of the acrylic cells. This chemical will most likely be purchased commercially. In the unlikely event that the collaboration synthesizes the dTPB, procedures will be developed to do so safely. The dTPB is dissolved in deuterated styrene using deuterated toluene. This mixture is applied to certain surfaces within the apparatus and allowed to evaporate to a uniform coating on the surface. Once the toluene evaporates, the materials are essentially harmless.

Chemicals will be stored in appropriate chemical-storage and flammable-materials cabinets. Waste-accumulation areas will be established, as needed, per ORNL and SNS standards and/or procedures, and responsible operations personnel will receive appropriate training. Access to Material Safety Data Sheets (MSDSs) is required for all chemicals in use. Personnel handling these materials are required to receive adequate training in specific chemical-handling procedures and proper use of MSDSs. Chemical use is subject to ORNL and SNS policies and procedures and is subject to the experiment safety-review process, as described in Section 7.1 of the FSAD.

2.12 Hoisting and Rigging Hazards

Assembly of the nEDM experiment apparatus at the SNS will require extensive use of the crane in the nEDM building. Custom lift fixtures will be required for many operations and will need to be certified.

Crane lifts at ORNL are conducted in accordance with the ORNL Hoisting and Rigging Program as specified and maintained in SBMS. The ORNL Hoisting and Rigging Program provides a structured approach for hoisting and rigging activities, establishes operator qualifications and training requirements, and ensures equipment is maintained in proper operating conditions.

2.13 Confined-Space Hazards

The nEDM cryogenic vessel and the liquid-helium storage tank outside the nEDM building are confined spaces. They are normally filled with liquid helium, but personnel may enter to perform work during assembly, commissioning, and maintenance. This situation is common to many SNS instruments.

Upon opening these spaces they will qualify as permit-required confined spaces until safe oxygen levels have been verified per OSHA Standard 29 CFR 1910.146., at which point they may be downgraded to a confined space not requiring a permit for access.

Workers who enter confined spaces will be trained and qualified in accordance with ORNL and SNS policies and procedures.

2.14 Electrical Hazards

In addition to the common electrical hazards associated with many SNS experiments, the nEDM experiment employs large vacuum pumps and systems that use 480 V 3-phase power. The hazards from this type of power are significantly worse than with 120 or 240 V power. There is also high voltage (~500 kV) with very low current ($<10^{-9}$ A) applied across the measurement cell via a capacitor of ~100 pF, resulting in a total stored energy of 5–10 J.

Experimental devices at the SNS are required to meet the intent of the NEC. Therefore NEC rules (e.g., fusing, connector types and cable types) are followed for instruments where reasonably achievable. FSAD Section 5.3.4 explains the approach followed to minimize the possibility for instrument systems to become an ignition source for fire. Installation of equipment and electrical utility routing will conform to applicable codes and requirements. Instrument equipment must be Underwriters Laboratories Inc. (UL) listed and/or factory mutual (FM) approved or requires approval by an appropriate SNS safety review committee.

All personnel performing service on equipment are required to receive training in, and adhere to, SNS ORNL lockout/tagout (LO/TO) policies. Work on energized equipment may be required. Only specifically qualified personnel will perform such work. Such individuals will be capable of working safely on energized circuits and will be familiar with proper use of precautionary techniques, PPE, insulating and shielding materials, and insulated tools. Any work on energized circuits must follow applicable SBMS procedures. This hazard is a common industrial hazard and is well controlled by SNS policies, procedures and training, per ORNL SBMS, NFPA 70 E is being followed.

2.15 Mechanical Hazards

As with most SNS experiments, nEDM will contain rotating machinery including pumps, blowers, motors (secondary shutter), etc. Power tools, fork lifts, dollies, etc., will be used during assembly, commissioning, and maintenance.

These mechanical hazards are considered to be standard industrial hazards adequately controlled by ORNL and SNS policies and procedures.

Appendix A

Hazard Identification Summary Tables

Tables A-1–A-5 on the following pages contain the Hazard Screening worksheets used to identify potential hazards associated with the nEDM experiment that are detailed in this analysis.

Table A-1 nEDM Hazard Screening Worksheet, Sheet 1

Hazard Energy Sources and Materials		Applicable?
Electrical	Battery banks	
	Cable runs	X
	Diesel generators	
	Electrical equipment	X
	Hot plates	
	Heaters	1
	High voltage	2
	Locomotive, electrical	
	Motors	6
	Pumps	X
	Power tools	3
	Switchgear	
	Service outlets, fittings	X
	Transformers	
	Transmission lines	
	Underground wiring	
	Wiring	X
	Other	
Thermal	Bunsen burner, hot plate	
	Electrical equipment	X
	Furnaces	
	Boilers	
	Lasers	4
	Electrical wiring	X
	Welding surfaces	3
	Engine exhaust	5
	Heaters	1
	Steam lines	
	Welding torch	3
	Exothermic reactions	
	Other	
Open Flame	Bunsen burners	
	Torches	
	Pilot lights	
	Gas welding	3
	Other	

"X" marks hazards considered applicable

Footnotes

1. Resistive heaters will be incorporated into the apparatus to increase rate of cryogen boil-off during warm-up phases. Will not be accessible.
2. High voltages (500 kV) at low currents (10^{-9} A) will be present across the measurement cell w/stored energy (5–10 J)
3. Possible use during assembly, commissioning, and maintenance.
4. Class 3B lasers used to measure voltage applied to the measurement cell.
5. Potential from delivery trucks at loading dock and from manlifts during assembly, commissioning, and maintenance.
6. Secondary shutter.

Table A-2 nEDM Hazard Screening Worksheet, Sheet 2

Hazard Energy Sources and Materials		Applicable?
Pyrophoric (plutonium and uranium metal)		
Pyrophoric (Other)		
SC* (Nitric acid and organics)		
SC* (Other)		
Combustible materials		1
Uncontrolled chemical reactions		
Flammable	Flammable gasses	
	Natural Gas	
	Spray paint	
	Compressed flammable gasses	
	Propane	
	Paint solvent	
	Cleaning/decontamination solvents	2
	Gasoline	
	Flammable liquids	2
	Flammable mixtures	
	Other	
Explosive/ Pyrophoric	Explosive gas	
	Dynamite	
	Sodium	
	Hydrogen (batteries)	
	Primer cord	
	Electric squibs	
	Nitrates	
	Dusts	
	Peroxides	
	Caps	
	Plutonium/uranium	
	Potassium	
	Superoxides	
	Hydrogen/tritium	
	Propane	
	Explosive Chemicals	
	Other	

"X" marks hazards considered applicable

Footnotes

1. The shielding design for the apparatus is not yet defined, but it could contain hydrocarbon-based elements.
2. Small quantities of acetone and alcohol will likely be used during assembly, commissioning, and maintenance.

Table A-3 nEDM Hazard Screening Worksheet, Sheet 3

Hazard Energy Sources and Materials		Applicable?
Radiological material		1
Fissile material		
Nonionizing radiation		2
Ionizing Radiation	Fissile material	
	Radiography equipment	
	Particle beams	3
	X-ray machines	
	Critical masses	
	Contamination	
	Radioactive materials	1
	Radioactive sources	4
	Other	
Hazardous Materials	Alkali metals	
	Asphyxiants	5
	Acetone	X
	Fluorides	
	Lead	6
	Drowning	
	Asphyxiation	5
	Ammonia (& compounds)	
	Beryllium (& compounds)	7
	Chlorine (& compounds)	
	Trichloroethylene	
	Decontamination solutions	8
	Dusts and particles	
	Sandblasting particles	
	Metal plating	
	Herbicides	
	Insecticides	
	Bacteria	
	Viruses	
	Biological	
	Carcinogens	
	Oxidizers	
	Corrosives	
	Other toxics	
	Other	

"X" marks hazards considered applicable

Footnotes

1. Potential for contamination of beamline components and measurement cell possible.
2. Radio-frequency spin flippers, "dressing" coils, and neutron spin guide magnetic fields.
3. Radiation level can be elevated around beam tubes, especially if shielding is removed. If shutter is not closed, gamma and neutron radiation level can be high at the experiment location.
4. Test sources (alpha and beta) will be used during assembly, commissioning, and maintenance.
5. Large volumes of cryogens (helium and nitrogen) are used. Sudden release represents asphyxiant hazard.
6. Lead shielding use likely. Soldering during assembly, commissioning, and maintenance.
7. Thin beryllium foils likely to be incorporated into entrance window.
8. Acetone and alcohol likely used in small quantities for cleaning purposes during assembly, commissioning, and maintenance.

Table A-4 nEDM Hazard Screening Worksheet, Sheet 4

Hazard Energy Sources and Materials		Applicable?
Kinetic—Linear and Rotational (Friction)	Belts	
	Bearings	
	Presses	
	Grinders	
	Crane loads (in motion)	1
	Vehicles	2
	Rail cars	
	Fork lifts	1
	Carts	1
	Dollies	1
	Centrifuges	
	Drills	1
	Saws	1
	Shears	1
	Fans	
	Gears	
	Motors	3
	Power tools	1
	Other	
Potential (Pressure)	Gas bottles	4
	Gas receivers	
	Pressure vessels	7
	Coiled springs	
	Boilers	
	Heated surge tanks	
	Autoclaves	
	Furnaces	
	Stressed members	
	Steam headers/lines	
	Other	5,6,7

"X" marks hazards considered applicable

Footnotes

1. Use likely during assembly, commissioning, and maintenance.
2. Delivery trucks.
3. Secondary shutter.
4. Not explicitly anticipated, but possible use of compressed gases for some test apparatus.
5. Vacuum volume within neutron beamline and inside apparatus.
6. Pressure potential present in the form of cryogenic liquids (helium and nitrogen) which will release pressure when heated.
7. Liquid-helium storage tank (pressure vessel) outside nEDM building.

Table A-5 nEDM Hazard Screening Worksheet, Sheet 5

Hazard Energy Sources and Materials		Applicable?
Potential (Height/Mass)	Stairs	X
	Lifts	1
	Cranes	1
	Elevated doors	X
	Loading docks	X
	Hoists	1
	Elevators	
	Trucks	1
	Jacks	1
	Scaffolds and ladders	2
	Pits	
	Elevated work surfaces	2
	Mezzanines	X
	Other	
Firearm discharge (puncturing)		X
Nonfacility event (explosion)		X
Nonfacility event (power outage)		X
Nonfacility event (aircraft crash)		X
Nonfacility event (transportation)		X
Nonfacility event (fire)		X
Nonfacility event (other)		
Natural Phenomena	Earthquake	X
	Flood	
	Lightning	X
	Rain	
	Snow, ice	X
	Freezing weather	
	Straight wind	X
	Tornado	X
	Other	
Vehicles in Motion	Airplane	
	Helicopter	
	Train	
	Heavy construction equipment	
	Truck/car	1
	Forklift/lift truck	X
	Other	

"X" marks hazards considered applicable

Footnotes

1. Possible use during assembly, commissioning, and maintenance.
2. Detector apparatus is 6 m in height. Permanent scaffolds needed for access during assembly, commissioning, and maintenance.

Arizona State University

University of California at Berkeley

California Institute of Technology

Duke University

Hahn-Meitner Institut

Indiana University

Oak Ridge National Laboratory

University of Illinois, Urbana-Champaign

University of Kentucky

Massachusetts Institute of Technology

North Carolina State University

Simon-Frasier University

University of Tennessee

Yale University

Los Alamos National Laboratory